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NOAA Fisheries ***Ecosystem-based Fisheries Management Road Map***
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Executive Summary

NOAA Fisheries has long recognized the importance of implementing ecosystem-based fisheries management (EBFM) in order to explicitly account for environmental changes and make trade-off decisions for actions that impact multiple species. These decisions would otherwise be made implicitly with strictly single-species management. The explicit treatment, transparent examination, and analytical exploration among the trade-offs across the many objectives in a given region are key outcomes resulting from the execution of EBFM.

NOAA Fisheries recently formalized its commitment to doing EBFM through the release of its EBFM Policy. The Policy defines EBFM, describes its benefits, discusses how it relates to existing living marine resource management legal authorities and requirements, establishes a framework of six Guiding Principles to enhance and accelerate the implementation of EBFM within NOAA Fisheries, and builds on past progress and clarifies the agency's commitment to integrating its management programs for living marine resources and their habitats.

The NOAA Fisheries EBFM Road Map builds upon the Policy by providing a national implementation strategy for the Policy. This Road Map describes how to operationalize the Policy's six Guiding Principles through a series of core components for each guiding principle.

The six Guiding Principles, with their associated core components, are:

1. Implement ecosystem-level planning
    - Engagement Strategy
    - Fishery Ecosystem Plans
2. Advance our understanding of ecosystem processes
    - Science to Understand Ecosystems
    - Ecosystem Status Reports
3. Prioritize vulnerabilities and risks to ecosystems and their components
    - Ecosystem-Level Risk Assessment
    - Managed Species, Habitats and Communities Risk Assessment
4. Explore and address trade-offs within an ecosystem
    - Modeling Capacity
    - Management Strategy Evaluations
5. Incorporate ecosystem considerations into management advice
    - Ecosystem-Level Reference Points
    - Ecosystem Considerations for Living Marine Resources
    - Integrated Advice for Other Management Considerations
6. Maintain resilient ecosystems
    - Resilience
    - Community Well Being

These Guiding Principles and the actions contained within them are the actionable steps for the implementation of EBFM within NOAA Fisheries.

NOAA Fisheries will review and, as appropriate, update the Road Map every five years. This will enable NOAA Fisheries to meet further NOAA guidance on EBFM or as the needs of NOAA Fisheries and its partners evolve. Key to the successful implementation of EBFM will be trade-off analyses regarding prioritization of various activities in each region.

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1.0 Background, Purpose, and Scope of the EBFM Road Map

1.1 Background

It is NOAA's National Marine Fisheries Service (NOAA Fisheries) policy to implement Ecosystem-based Fisheries Management (EBFM). This policy is formalized in the EBFM Policy Statement[1]. The EBFM Policy recognizes the importance of EBFM and articulates NOAA Fisheries' commitment to it.

The EBFM Policy describes the background, definition, rationale, legislative context, and major Guiding Principles for executing EBFM. NOAA Fisheries defines EBFM as:

"a systematic approach to fisheries management in a geographically specified area that contributes to the resilience and sustainability of the ecosystem; recognizes the physical, biological, economic, and social interactions among the affected fishery-related components of the ecosystem, including humans; and seeks to optimize benefits among a diverse set of societal goals."

1.2 Purpose

This EBFM Road Map is intended to guide the implementation of the EBFM Policy over the next 5 years. It describes recommended Actions to address each of the Policy's six Guiding Principles for near-term work. Given the breadth and magnitude of implementing EBFM, the Road Map is an initial national articulation of priorities that the agency will continue to review, revising and building on the efforts noted herein, with another installment of the Road Map planned in five years.

The EBFM Road Map calls for increased coordination across all the Living Marine Resource (LMR) science and management efforts in each U.S. marine region (Figure 1). This Road Map is intended to ensure that: no major pressures affecting LMRs and their habitats are omitted; NOAA Fisheries executes the correct analytical level of assessment, addresses relevant ecosystem linkages, accounts for ecosystem-level features and cumulative impacts; and the frequency and scope of LMR assessments align with the broader ecosystem and fishing community dynamics. A major objective of this Road Map is to identify complementary efforts that would benefit from additional coordination; NOAA Fisheries will ensure that its various efforts are well coordinated among NMFS Science Centers, Regions, and Headquarter Offices, Regional Fishery Management Councils, States, and key stakeholders. Ultimately, all factors affecting fisheries resources or, in turn, are affected by them need to be considered in a systematic manner in the science and management pertaining to these resources.

[1] https://www.st.nmfs.noaa.gov/Assets/ecosystems/ebfm/Draft_EBFM_Policy_9.9.2015_for_release.pdf

The NOAA Fisheries EBFM implementation is guided by six Guiding Principles outlined in the EBFM Policy Statement:

1. Implement ecosystem-level planning
2. Advance our understanding of ecosystem processes
3. Prioritize vulnerabilities and risks to ecosystems and their components
4. Explore and address trade-offs within an ecosystem
5. Incorporate ecosystem considerations into management advice
6. Maintain resilient ecosystems

These Guiding Principles help NOAA Fisheries prioritize and coordinate across a range of management objectives to more fully adopt a systematic, integrated approach based on a solid, continually advancing, and innovative science foundation. Adopting and meeting these Guiding Principles is an ongoing effort that will harmonize our endeavors to meet myriad mandates in a more integrated, systematic manner.

This Road Map describes how NOAA Fisheries will translate these Guiding Principles into actionable steps to implement EBFM. The Road Map provides greater detail for each of the Guiding Principles and delineates, in broad terms, what is required to make EBFM operational. This Road Map describes operational EBFM from a national perspective while allowing for flexibility in regional application.

1.3 Scope

The implementation of EBFM must be scalable and flexible with respect to geographic scope and extent. The Road Map recognizes that, because of the many major jurisdictions in the United States for LMR management (Figure 1), management must occur at multiple spatial, temporal, and governance scales. NOAA Fisheries needs communication and coordination with multiple partners to execute EBFM at all these jurisdictional levels.

This Road Map acknowledges the multiple scales at which NOAA Fisheries could be involved to execute EBFM. The components of each Guiding Principle are established to be flexible enough to accommodate varying geographic or governance scales. The primary emphasis and focus of the Road Map is on the regional Fishery Management Councils (FMCs) and the associated Large Marine Ecosystems (LMEs) in each region. This approach capitalizes on NOAA Fisheries' Fisheries Science Centers (FSCs) and Regional Offices (ROs) existing structures and strengths, but also allows for the requisite flexibility to address other jurisdictions that are germane to specific regions and locales.

NOAA Fisheries recognizes that many of these jurisdictions have already made significant progress toward many of the components of the Road Map. With this Road Map, we provide a set of Actions to further support advances in EBFM.

This Road Map recognizes the need for a framework to integrate and synthesize a wide range of information. The Integrated Ecosystem Assessment (IEA[2]) approach is an appropriate and increasingly adopted framework to provide a coherent theme for integrating all the various inputs, products, and efforts requisite for EBFM (Box 1-IEAs). IEAs are an internationally accepted framework for translating marine ecosystem science into a range of management advice. Although able to address multiple ocean-use sectors—and originally intended for the multiple ocean-use, multi-sector Ecosystem-based Management (EBM; Box 2-EBM Levels)—IEAs also serve as a basis for implementing EBFM. There is no need to develop a new framework or process; rather, NOAA Fisheries will adopt the IEA approach to execute the Guiding Principles for achieving EBFM, and insert outputs from the IEA process into existing jurisdictional governance venues.

NOAA Fisheries recognizes that implementing EBFM requires explicit action to advance both science and management considerations. Certainly NOAA Fisheries aims to advance the science capability at its FSCs, but recognizes that it also needs inputs from a wide array of partners to further advance the science necessary to support EBFM. NOAA Fisheries also recognizes that management actions and decisions occur in its ROs/FSCs and in its partner organizations like FMCs, Interstate Fishery Commissions, States, Tribal governments, and others. NOAA Fisheries acknowledges that advances are also needed in management to implement EBFM, and this Road Map identifies supportive actions where LMR management is led by partners external to NOAA Fisheries. This Road Map aims to clarify that actionable steps are recommended in both the science and management contexts.

NOAA Fisheries executes many interrelated efforts to monitor, model, and manage the nation's LMRs and marine ecosystems (Figure 2). NOAA Fisheries has been working toward EBFM for many years, with recognition of the need for ecosystem considerations in the Stock Assessment Improvement Plan (SAIP), the establishment of the Fisheries and the Environment Program (FATE), development of programs for IEA efforts, the Habitat Assessment Improvement Plan (HAIP), a recent NOAA Fisheries National Climate Science Strategy (NCSS), and a Protected Species Improvement Plan (PR-SAIP), among other efforts. NOAA Fisheries recognizes that these efforts are complementary, and that they collectively advance EBFM. This EBFM Road Map calls for increased coordination across the analytical and management efforts in each region to ensure that no major pressures affecting LMRs are omitted, that we apply the correct analytical level of assessment, that cumulative and synergistic system-level effects are not overlooked, and that the frequency of assessments done for LMRs aligns with the broader dynamics of the ecosystem and fishing communities.

2.0 Implementation of EBFM Guiding Principles

[2] https://www.st.nmfs.noaa.gov/ecosystems/iea/index

NOAA Fisheries views the EBFM Road Map not as an additional requirement for meeting our mandates, but rather as a shift in how it meets them. NOAA Fisheries also recognizes that many of these efforts are already underway. A key point for developing this EBFM Road Map is to leverage these extant efforts and more effectively coordinate among them.

This is an internal NOAA Fisheries document intended to outline a process for our employees, as well as how NOAA Fisheries hopes to work with our partners and stakeholders. NOAA Fisheries recognizes the role that Councils, Commissions, and other critical partners play in shaping priorities, policy, and management approaches for our fisheries with respect to EBFM implementation.

Upon finalization of this document, the afore-mentioned programs will determine whether additional funding will be needed for this important work and develop suitable requests, if necessary. Until these requests have been funded, the action items below will be done where current funding permits. As noted above, trade-off analyses will be an important component of the decision process for deciding on whether funding for existing programs should be reprogrammed to support new efforts contributing to EBFM. NOAA Fisheries is committed to making EBFM a priority via the execution of this Road Map, while remaining committed to address regionally established needs and emphases.

2.1 Implement ecosystem-level planning– Guiding Principle 1

Guiding Principle 1 calls for the use of Fishery Ecosystem Plans (FEPs), or similar documents, to describe and integrate ecosystem goals, objectives, and priorities across multiple fisheries and the effects of various pressures on fisheries within an ecosystem. NOAA Fisheries cannot fully implement EBFM without significant engagement from its partners and interested stakeholders. To implement ecosystem-level planning, Guiding Principle 1 calls for NOAA Fisheries to:

- Facilitate continued participation of external federal, state (including territories), council, commission, tribal, industry, and other non-governmental partners in the EBFM process
- Support and provide guidance or assistance to execute FEPs that are used as umbrella strategic planning documents to guide coordination and trade-off evaluation among Fishery Management Plans (FMPs), related documents, and other ecosystem components.

Such ecosystem-level planning would address long-term ecological, economic, and social goals, objectives, and priorities across NOAA Fisheries' multiple mandates and in partnership with its diverse stakeholders.

2.1.1 Develop engagement strategies to facilitate the participation of partners and stakeholders in the EBFM process (Guiding Principle 1a)

After requesting and receiving stakeholder input, NOAA Fisheries will develop national and regional EBFM engagement strategies to further this initial phase of awareness and engagement on EBFM. This will start with the launch of the Policy and Road Map for public review and comment. NOAA Fisheries will initiate and maintain a national dialogue on EBFM with its partners to ensure that we communicate underlying principles as well as the needs for and benefits from EBFM, while being open to input from those audiences and adjusting its efforts accordingly. Additionally, NOAA Fisheries will build on extant engagement efforts from the IEA program (Box 3- Engagement), the National Climate Science Strategy and its Regional Action Plans, Fishery Management Council (FMC) visioning processes, regular Council Coordination Committee meetings, NOAA's Aquaculture Policy, and similar efforts that serve as part of the ongoing engagement with partners and stakeholders regarding EBFM. Other engagement approaches will also be necessary, including webinars and other vehicles, to reach beyond the usual set of stakeholders.

Engaging with partners and stakeholders will allow NOAA Fisheries to better identify the management actions required to achieve agreed-upon results, identify those management actions that are not working, and address the management decisions that are currently made with large uncertainty. A useful tool for engagement is the development and use of conceptual models (Box 3- Engagement), which have helped to promote and support feedback on ecosystem modeling when developing objectives for a region. A transparent venue for all stakeholders to provide input and feedback on EBFM analyses will improve the implementation of EBFM. While FEPs are a good initial source to identify ecosystem-level goals and objectives for FMCs, it is important that multiple stakeholders and jurisdictions (not just FMCs) engage in this process.

2.1.2 Support development of Fishery Ecosystem Plans (Guiding Principle 1b)

Fishery Ecosystem Plans (FEPs) are policy planning documents that the FMCs or NOAA Fisheries may use to describe ecosystem objectives and priorities for fishery science and management, and to inform development of FMPs or FMP amendments (Box 4-FEPs). FEPs provide fisheries management with ecosystem-scale information on fundamental physical, chemical, biological, and socio-economic structures and functions of LMEs. They are valuable for describing the relationships between LMRs, human uses of those resources, and other human activities that affect LMRs and their habitats. By exploring fishery management options that simultaneously address multiple objectives, they may help the FMCs, NOAA Fisheries, and other agencies better address the cumulative effects of our actions on the environment.

FEPs have already been developed in several FMCs, primarily to explore ecosystem-wide issues under the Magnuson-Stevens Fishery Conservation and Management Act. A recent inventory documents the national progress made in the development of FEPs. Many FMCs are also implementing EBFM through FMPs. To better understand the scale and scope of EBFM activity within our multiple FMC processes, an inventory of best FMC practices for EBFM is needed.

NOAA Fisheries will build on a recently completed review of FEPs and conduct an inventory and gap analysis of EBFM efforts in FMPs across regions to establish a baseline understanding of existing approaches nationally and to identify areas ripe for further guidance. To a large extent, future FEPs will be designed *inter alia* to identify prioritized information to promote the implementation of EBFM.

Recommended Actions

EBFM Policy Statement Guiding Principles	#	EBFM Road Map Components	Overarching Goal	Action Items	Timing
Implement Ecosystem Level planning					
	1a	Engagement Strategy	Have EBFM Engagement Strategy for each region	Establish EBFM Point of Contact at each Regional Office, Fisheries Science Center, and Headquarters Offices	Short
	Develop engagement strategies to facilitate the participation of partners and stakeholders in the EBFM process			Develop National and Regional EBFM engagement strategies	Short
				Develop Standardized EBFM Policy and Road Map Materials for widespread use (e.g. NOAA Fisheries personnel, Sea Grant extension agents)	Short
				NOAA Fisheries supports any Ecosystem Plan Development Teams, Ecosystem Committees (or equivalent groups) that FMCs establish	Ongoing
				Explore more detailed facets of all Authorities, Mandates and Governance calling for EBFM, providing any necessary guidance to clarify or augment extant authorities and institutions	Mid
	1b	Fishery Ecosystem Plans	Assist Councils in the development of their FEPs for most of our 12 LMEs	Establish FEP Coordinator/Analyst for each NOAA Fisheries Region and in appropriate Headquarters Office	Short
	Support development of Fishery Ecosystem Plans			Review and develop inventory of existing FEPs and Ecosystem Considerations in FMPs, documenting best practices	Short
				Assist FMCs, as requested, in their development of new, or revision of existing FEPs	Ongoing

2.2 Advance our understanding of ecosystem processes– Guiding Principle 2

Ecosystem-level advice requires ecosystem-level science. Here, ecosystem-level science can be characterized by multidisciplinary information, collaborations and heightened coordination, and a drive to understand processes important to fishery resources. The holistic approach of EBFM recognizes the physical, biological, economic, and social complexities of managing living resources as an integrated system. As NOAA Fisheries moves toward implementation of EBFM, additional information will be required from many disciplines. Implementation of EBFM will result in better awareness of ecosystem status and trends as well as new understanding of the ecosystem processes relevant to fishery resources.

NOAA Fisheries will work to better understand the broader suite of ecosystem processes, drivers, threats, status, and trends of the nation's marine ecosystems to inform all levels of management advice, including:

- Conduct science to understand ecosystems
- Provide Ecosystem Status Reports for each Large Marine Ecosystem

2.2.1 Conduct science to understand ecosystems (Guiding Principle 2a)

The science programs within NOAA Fisheries are critically important for advancing the understanding of ecosystem processes—as are partnerships with universities, states, tribes, FMCs, other NOAA line offices, and other federal agencies. Modeling the processes, drivers, threats, status, and trends of our ecosystems is not possible without data collection programs to ensure that we have the requisite data to populate those models. As NOAA Fisheries implements EBFM, additional information will be needed from an array of scientific disciplines. A national review of the data collection programs is needed on a wide range of disciplines, including but beyond the typical abundance and basic biological data. For instance, needs that warrant inventory to identify gaps include diet identification and predator-prey interactions for LMR species, lower trophic level data, ecosystem productivity, interactions between protected and other species, habitat data and LMR species' habitat use, oceanographic data, and climate data.

An important challenge as we implement EBFM is to advance our understanding of processes as we discern the relative importance to fishery resources. NOAA Fisheries will work to better understand a broader suite of ecosystem processes, drivers, and threats, including:

- Measurable biogeochemical, biophysical, and ecological factors, processes, and interactions, such as:
    - Population dynamics and spatiotemporal distributions of LMRs
    - Trophic relationships (including predator-prey relationships and forage fish dynamics)

  - Oceanographic features and other environmental factors (including climate change and ocean acidification)
  - Habitat distribution status and predominant threats to ongoing habitat quality, and linking habitat to ecosystem productivity patterns
  - Effects of invasive species on ecosystem function
- Social and economic considerations, such as:
  - Social and economic factors that influence fishermen, seafood farmers, and other users of the marine environment
  - Economic welfare and social well-being of resource users and dependent communities
  - Community vulnerability and resilience
  - Non-market and existence values of marine mammals, turtles, seabirds, forage species, corals, and other marine species
  - Seafood production
  - Employment
  - Long-term social and economic impacts of resource depletion and recovery
  - Gear-specific location and intensity of fishing effort
  - Changes in domestic seafood supply and security
  - Changes in recreational fishing opportunities
- Interactions between fisheries, protected species, and habitats

Results of end-to-end research efforts for EBFM enhance our scientific advice. These results complement the stock assessments that are a mainstay of the fishery and protected species management process. Such studies need to cut across scientific disciplines and accelerate the application of ecosystem research results to NOAA Fisheries scientific advice. NOAA Fisheries will evaluate current investments in system-level research, utilize existing mechanisms to support an appropriate balance between traditional stock oriented research and more interdisciplinary end-to-end studies, and develop budget initiatives to bolster this research.

In addition, NMFS proposes to convene a biennial conference dedicated to EBFM research and management. This venue will provide an environment to exchange research results, communicate best practices, and gather experts to address scientific and management challenges to EBFM. The development of a biennial conference will build off of regular and extant FATE, National Habitat Assessment Workshops (NHAW), National Stock Assessment Workshops (NSAW), National Ecosystem Modeling Workshops (NEMoW), and IEA meetings and will elevate NOAA Fisheries science and management needed to implement EBFM.

2.2.2 Provide Ecosystem Status Reports for each Large Marine Ecosystem (Guiding Principle 2b)

Ecosystem Status Reports (ESRs) for specific LMEs will be produced periodically and are intended to provide a brief summary of the status of ecosystem dynamics, including pressures and responses (Box 5-ESRs). These reports are informational products that

provide overall system context using the status and trends of leading indicators. Additionally, by identifying data useful for further analytical effort, ESRs can highlight key data gaps and support future technological development and data collection efforts.

Developing and regularly updating ESRs in each region require an efficient process and sufficient resources. ESRs are maturing conceptually and being used by NOAA Fisheries partners, such as by various FMCs within Stock Assessment and Fisheries Evaluation reports. Their use to inform a plethora of other LMR management needs (e.g., bycatch reports, Status of Stocks, stock assessment reviews, status reviews, 5-year ESA and EFH reviews) is not yet fully realized. To implement EBFM, ESRs need to advance in sophistication and diagnostic capability. An effective system for delivering the reports and related advisories will enhance efficiencies in their production time and relevance to stakeholders.

Recommended Actions

EBFM Policy Statement Guiding Principles	#	EBFM Road Map Core Components	Overarching Goal	Action Items	Timing
Advance our understanding of ecosystem processes					
	2a	Science to Understand Ecosystems	Have robust, innovative, Internationally-recognized science programs to support management	Advance resources to conduct EBFM	Ongoing
	Conduct Science to Understand Ecosystems			Develop National EBFM Performance measures	
				Develop capacity for NOAA Fisheries to conduct end-to-end ecosystem studies	Short
				Conduct biennial EBFM Science & Management Conference	Short
				Develop and maintain core data and information streams	Ongoing
					Ongoing
	2b	Ecosystem Status Reports	Have ESRs for most of our 12 LMEs	Conduct a national review of existing ESRs to assess Fisheries Science Center (FSC) indicator information needs to identify where ESRs address similar indicators across LMEs	Short
	Provide Ecosystem Status Reports for each Large Marine Ecosystem			Establish routine, regular and dynamic reporting of ESRs for each LME	Mid

2.3 Prioritize vulnerabilities and risks of ecosystems and their components—Guiding Principle 3

Resources to manage our nation's LMRs and their ecosystems are finite. NOAA Fisheries and its partners must identify and prioritize which ecosystems, habitats, or LMRs warrant additional attention. Rapid evaluation of key pressures, drivers, and threats is needed to identify and mitigate them, both to rebuild depleted species, produce additional seafood, and to improve resilience of the ecosystems in which they live. Attempting such triage exercises can be daunting, but is warranted to best capture the risks facing the nation's managed species and ecosystems. Building off work and information from the previous two Guiding Principles, prioritization through existing risk and vulnerability analyses will help to focus responses to the ever-changing and increasingly dynamic pressures that managers responsible for marine ecosystem management face.

NOAA Fisheries needs to evaluate and address the individual and cumulative drivers for threats to and pressures on the physical, chemical, biological, social, and economic components of marine ecosystems. This should take into account the comprehensive and systematic risk, vulnerability, and susceptibility of LMRs and ecosystems, including:

- Identify the ecosystem-level, cumulative risk (across LMRs, habitats, ecosystem functions, and associated fisheries communities) in each region and the relative vulnerability to human and natural pressures
- Identify the individual and cumulative pressures that pose the most risk to those vulnerable resources and dependent communities

This starts at an ecosystem level to identify those overarching, common risks across all taxa. Doing so will allow for efficiency of effort, as those major risks can then be explored for individual taxa or habitats, fishery participants, and dependent communities.

2.3.1 Identify ecosystem-level, cumulative risk (across LMRs, habitats, ecosystem functions, and associated fisheries communities) and vulnerability to human and natural pressures (Guiding Principle 3a)

NOAA Fisheries will conduct comprehensive, ecosystem-level risk assessments. These analyses will allow jurisdictions (i.e., fishery management authorities such as NOAA Fisheries, Councils, Commissions, etc.) to explore multiple pressures and drivers, including climate and other abiotic factors specific to each jurisdiction, to better understand the cumulative effects on the ecosystem and its fisheries. Ideally, this initial suite of products would be developed and evaluated at an ecosystem-level. The analyses help prioritize the management and scientific needs in each region. Taking a systemic, or aggregate approach, helps to identify overarching, common risks across all habitats, taxa, ecosystem functions (Box 6 -Agg Risk), fishery participants and dependent communities. It also helps to capture the potential cumulative or synergistic effects of multiple pressures.

2.3.2 Identify the individual and cumulative pressures that pose the most risk to vulnerable resources and dependent communities (Guiding Principle 3b)

Risk assessments need to be conducted to evaluate the vulnerability of the 800+ US managed and non-managed LMR species with respect to their exposure and sensitivity to ecological and environmental factors affecting their populations. Habitat risk assessments are also needed to identify those species that are habitat-limited and locales that will be most stressed by human activities and changes in oceanographic conditions and that are most important for conservation. These assessments will be useful in prioritizing which of the LMRs and habitats need to be examined in more detail or more frequently, or where conservation actions are most needed, and for which LMRs routine (even trend or survey data) updates are adequate. Although they must be comprehensive in scope, risk assessment methods can use a wide range of readily available qualitative and ordinal data, to rapidly and systematically assess those factors that affect managed species or habitats. An example of an existing rapid risk assessment tool is the Productivity and Susceptibility Analysis (PSA). Another example is the fisheries Climate Vulnerability Assessment, first implemented in the Northeast region and now planned for other regions as part of the NMFS Climate Science Strategy (NCSS). Habitat assessment prioritization processes have been completed in three NOAA Fisheries regions. Additionally, a comprehensive stock assessment prioritization effort is ongoing (Box 7- SA Priority). Programmatic analyses that will satisfy the requirements of the National Environmental Policy Act (NEPA) need to be conducted to plan for major projects such as aquaculture production in federal waters (for regions where offshore aquaculture is most likely to occur) or coastal and offshore development and infrastructure. The overall outcome of these risk assessments is to identify the LMRs and habitats for which broader ecosystem considerations are highest priority.

Fisheries communities are also at risk as LMR dynamics change in response to a range of human and natural factors. Risk assessment of fleets, ports, and related communities is warranted as those human elements of the ecosystem will need to adapt to changing ecosystem and management conditions, and face related economic and social consequences.

Recommended Actions

EBFM Policy Statement Guiding Principles	#	EBFM Road Map Core Components	Overarching Goal	Action Items	Timing
Prioritize vulnerabilities and risks					
	3a	Ecosystem-level Risk assessment	Evaluate majority of main risks, including Climate Change, for most of our 12 LMEs	Conduct Systematic Risk Assessments for relevant NOAA regional ecosystems	Long
	Conduct comprehensive ecosystem-level risk assessment			Explore protocols for conducting regional habitat risk assessments for those areas known to serve important ecological functions for multiple species groups or will be especially vulnerable or important in the face of climate change	Mid
				Ensure more integrated, systematic risk assessments are used to coordinate regional NEPA analyses	Long
	3b	Managed species, Habitats & Communities Risk Assessment	Evaluate risks for all of our managed species	Ensure that factors which impact 800+ US managed species are being considered	Ongoing
	Conduct risk assessment for each of NOAA Fisheries' Managed Species, Habitats and Fishing Communities			Conduct Habitat Assessment Prioritization for all NOAA Fisheries regions	Mid
				Conduct Fishing Community vulnerability assessments for all NOAA Fisheries regions	Short

2.4 Explore and address trade-offs within an ecosystem— Guiding Principle 4

Once priorities have been established following the risk and vulnerability assessments, trade-offs need to be evaluated within and between activities and components in the associated systems, including those related to alternate management strategies and evaluation of potential impacts. In close cooperation with its partners, NOAA Fisheries supports the consideration of and efforts to take into account various trade-offs when considering the independent and the cumulative effects of natural and human pressures on the ecosystem, including:

- Analyze trade-offs to optimize total benefits from all fisheries within each ecosystem or jurisdiction. This will be done by taking into account regional socio-

economic considerations and ecosystem-specific policy goals and objectives (e.g., MSA, MMPA, ESA, National Aquaculture Act, etc.) that may apply
- Develop management strategy evaluation capabilities to better conduct ecosystem-level analyses that provide ecosystem-wide management advice

NOAA Fisheries recommends using management strategy evaluations (MSEs) to explore trade-offs among the objectives identified in Guiding Principle 1 above, and remaining cognizant of the statutory obligations under the ESA, NEPA, MMPA, National Aquaculture Act, MSA, et seq. as noted in the EBFM Policy. These need to be contrasted with ecosystem-level reference points and benchmarks, so that cumulative impacts or specific objectives are not overlooked.

2.4.1 Analyze trade-offs for optimizing benefits from all fisheries within each ecosystem or jurisdiction, taking into account ecosystem-specific policy goals and objectives, cognizant that ecosystems are composed of interconnected components (Guiding Principle 4a)

NOAA Fisheries needs to establish sufficient EBFM modeling capacity to analyze trade-offs. Before establishing reference points against which objectives can be measured, and before establishing MSE protocols and processes, the quantitative basis for exploring ecosystem dynamics is required. While NOAA Fisheries has some existing capacity, it still needs to bolster this capability, including both complex and simple models and tools. Fully coupled, end-to-end models capturing the entire Earth-system, physical, chemical, geological, biological, and socio-economic facets of ecosystem dynamics are not always possible or necessary in every locale. Other models of intermediate complexity also can be used and should be developed. However, a suite of data-poor tools, techniques, and models exists to begin modeling for EBFM practically everywhere. Development of an EBFM analytical toolbox is needed, particularly one that includes ecosystem modeling tools and best practices; data-poor qualitative and semi-quantitative tools; and related decision support tools. This toolbox would be used in conjunction with Fisheries and Protected Species toolboxes and in conjunction with risk assessment tools. NOAA Fisheries needs to bolster its ecosystem modeling capacity and harmonize its ecosystem modeling efforts with its fish assessment and protected species modeling efforts. Comparisons across multiple models are ongoing, but expansion of multi-model inference is prudent.

2.4.2 Develop Management Strategy Evaluation capabilities to better conduct ecosystem-level analyses to provide ecosystem-wide management advice (Guiding Principle 4b)

Assessing and appropriately accounting for uncertainty when making management decisions for LMRs is critical. MSEs allow jurisdictions to test management options under various ecological and environmental conditions. As such MSEs are an important tool to help develop robust management alternatives in the face of difficult conditions. A wide range of simulations using MSEs will help determine which management options will most likely accomplish desirable outcomes and are most robust to accommodate a range of considerations. MSEs help evaluate trade-offs among different management scenarios and can highlight key gaps in data and understanding of ecosystem processes

and human impacts. Executing MSEs at the ecosystem level can capture major drivers, pressures, and responses, as well as emergent properties that would be missed if explored on a taxa-by-taxa basis. NOAA Fisheries will ensure that Ecosystem MSEs link to multispecies and single species MSEs, inclusive of economic, socio-cultural, and habitat conservation measures.

Innovative means for visualizing complex MSE and model output also are needed. The use of social media, interactive graphics, and engaging storytelling has become commonplace and is now almost expected. Typically we present model results in complex, static graphic format. As technologies and tools continue to develop, the ability to more interactively allow stakeholders to "play" possible fishing, aquaculture, mitigation, or other management scenarios not only seems warranted, but better captures the truest sense of partnership when making multi-objective decisions.

Recommended Actions[3]

EBFM Policy Statement Guiding Principles	#	EBFM Road Map Core Components	Overarching Goal	Action Items	Timing
Explore and address trade-offs within an ecosystem					
	4a	Modeling Capacity	Have sufficient analytical capacity to evaluate a full range of tradeoffs	Assess and bolster ecosystem and LMR modeling needs in each FSC	Ongoing
	Establish sufficient EBFM modelling capacity to analyze trade-offs			Encourage and expand the use of multi-model inference	Ongoing
				Establish suitable review venues and deliberative bodies for ecosystem models and associated information in each FSC region	Mid
	4b	Management Strategy Evaluations	Have MSEs that cover most our 12 LMEs and Fisheries	Develop functional system-level MSEs	Mid
	Developing Management Strategy Evaluation Capabilities			Explore novel Harvest Control Rules (HCRs) and develop associated guidelines, especially to test & explore robust Ecosystem Level strategies	Long
				Create "X-prize" like competition for visualizing and communicating complex ecosystem model and MSE outputs	Long

[3] In conjunction with NGSA/SAIP and from SA Program reviews, each FSC to get one FTE for conducting MSEs as operating models. This increase in MSE capacity will augment this EBFM effort in coming years.

[4] Fish are defined under the MSA as finfish, mollusks, crustaceans, and all other forms of marine animal and plant life other than marine mammals and birds, and would include deep-sea corals and sponges (16 U.S.C. §1802(12)).

2.5 Incorporate ecosystem considerations into management advice – Guiding Principle 5

The EBFM Policy notes that implementing EBFM will assist the agency in better meeting its mandates to sustainably manage the nation's trust LMRs and maintain resilient ecosystems. NOAA Fisheries recognizes the value of placing its resource management efforts into a broader ecosystem context. LMR management should consider best available ecosystem science in decision-making processes (within our legal and policy frameworks), in order to:

- Develop and monitor ecosystem-level reference points
- Incorporate ecosystem considerations into appropriate LMR assessments, control rules, and management decisions
- Provide integrated advice for other management considerations, particularly applied across multiple species within an ecosystem

Implementation of this principle will focus on three areas. First, NOAA Fisheries will clarify the concept of ecosystem-level reference points and how they could be used in the context of already required species or fisheries reference points. This will require close coordination among FSC, RO, FMC, States, and other key stakeholders. Second, NOAA Fisheries has already begun work to incorporate ecosystem information into species and stock assessments used to implement statutorily required reference points. NOAA will continue to advance that work. Third, NOAA has several mandates that are not reference point–driven but whose implementation could either contribute information about ecosystem status or could be bolstered with additional ecosystem information. This includes requirements to minimize bycatch and impacts to habitat as practicable. It also includes the well-being of coastal communities and participating persons in the fisheries. Fourth, NOAA Fisheries will use ecosystem information in regional studies of federal waters where offshore aquaculture operations (e.g. for use in NEPA analyses) are likely to occur and in studies of ecosystem carrying capacity important to seafood farming in coastal areas.

Evaluating cumulative impacts of proposed management actions for LMRs and their ecosystems and identifying alternative actions that achieve societal goals will further inform EBFM decisions. Cumulative and synergistic impacts are difficult to identify on a species-by-species basis, and systemic analyses will help to identify any such impacts. The NEPA process will be utilized to better evaluate these cross-cutting potential impacts. In conjunction with results of systemic risk assessments (sect. 2.3.1), these analyses will help delineate those facets that result in the most pressure or largest constraints for achieving desired stock, seafood production, and ecosystem status.

2.5.1 Develop and monitor Ecosystem-Level Reference Points (Guiding Principle 5a)

Ecosystem-level reference points (ELRPs) and thresholds can inform the use of statutorily required reference points. These reference points could help to identify key dynamics, emergent ecosystem properties, or major ecosystem-wide issues that impact

multiple species, stocks, and fisheries over the long term that could be missed if decision criteria were developed and examined only on a species-by-species basis. These ecosystem or aggregate level decision criteria will also be used to track major structural or systemic issues that impact all LMRs. A number of options for developing and using ELRPs could be applicable under different scenarios, including measures of aggregate or system level yield. Evaluation of simple summations of LMR reference points in the context of total ecosystem productivity can aid in evaluating overall fisheries performance in an ecosystem.

2.5.2 Incorporate ecosystem considerations into appropriate LMR assessments, control rules, and management decisions (Guiding Principle 5b)

NOAA Fisheries uses a variety of reference points to manage fisheries. Reference points that incorporate ecosystem considerations may be helpful in the management of at least some fisheries or species in the near term, and all fisheries in the long term. These considerations may include factors impacting stock structure, dynamics, and production that are considered important for those LMRs, particularly as identified by risk assessments (c.f. Section 2.3.2) for stocks which have been identified as imperative to account for ecosystem considerations factors (Box 9-Incl. ecosystem info). NOAA Fisheries is clear that incorporating ecosystem considerations may not be necessary or feasible for all 800+ US managed species, but it will be increasingly worth monitoring for those species identified in such risk assessments, particularly in the context of a changing climate (as in conjunction with the NCSS). Ecosystem factors may be incorporated directly into parameters in stock assessment calculations, considered in stock assessment plan team reviews of actions, or accounted for when setting harvest control rules (HCR; Box 10-MS HCR), or even reviewed by FMCs' Scientific and Statistical Committees (SSCs). Ecosystem considerations for these LMRs will provide a more comprehensive understanding of the uncertainty associated with estimating biological reference points, and stock status that lead to management advice.

2.5.3 Provide systematic advice for other management considerations, particularly applied across multiple species within an ecosystem (Guiding Principle 5c)

Ending and preventing overfishing and rebuilding overfished stocks are required under the MSA, and the ESA and MMPA have requirements pertaining to the conservation and recovery of protected species. There are also other required management considerations that would benefit from coordination across all taxa in an ecosystem.

NOAA Fisheries is required under the MSA to identify and describe essential fish habitat (EFH) for managed species and under the ESA to designate critical habitat for endangered species. In conjunction with the NOAA Habitat Blueprint, NOAA Fisheries Habitat Assessment Improvement Plan (HAIP), and regional habitat assessment prioritization processes within the next ten years NOAA Fisheries will support each FMC in considering EFH at a system level by 1) updating EFH information in FMPs or FEPs (NOAA Fisheries recommends that EFH information be reviewed every five years), 2) identifying habitat areas of particular concern that are known to support important ecological functions for multiple species or species groups or may be especially

vulnerable or provide essential functions in a changing climate, and 3) establishing habitat conservation objectives for those areas and indicators to measure progress in achieving those objectives.

NOAA Fisheries is required under MSA, to the extent practicable, to minimize bycatch of fish, and, to the extent bycatch cannot be avoided, minimize the mortality of bycatch (16 U.S.C. §1851(a)(9))[4]. In conjunction with the NOAA Fisheries Bycatch Reduction Strategy, NOAA Fisheries will integrate bycatch-related efforts with the EBFM Policy and this Road Map. NOAA Fisheries will also take into account Take Reduction Plans under the MMPA. Information resulting from work to implement the Bycatch Reduction Strategy will contribute to NOAA Fisheries' implementation of the EBFM policy.

NOAA Fisheries assists in the development of aquaculture under the National Aquaculture Act, which calls for increasing U.S. seafood production, and directly permits aquaculture in federal waters for species regulated under MSA or covered by an aquaculture FMP. The agency consults with federal permitting agencies under ESA and MSA essential fish habitat provisions for aquaculture activities in both state and federal waters, and develops and uses aquaculture techniques in the restoration of species and habitats. Under both NEPA and the National Aquaculture Act, NOAA Fisheries will evaluate the ecosystem-level effects of aquaculture.

[4] Fish are defined under the MSA as finfish, mollusks, crustaceans, and all other forms of marine animal and plant life other than marine mammals and birds, and would include deep-sea corals and sponges (16 U.S.C. §1802(12)).

Recommended Actions[5]

EBFM Policy Statement	#	EBFM Road Map Core Components	Overarching Goal	Action Items	Timing
Incorporate Ecosystem Considerations into Management Advice					
	5a	Ecosystem-level reference points	Establish and use Ecosystem Level Reference Points	Explore best practices for estimating and using system-wide or aggregate group harvest limits, in context of OY, Annual Catch Limits (ACL), and Harvest Control Rules (HCR)	Mid
		Develop and Monitor Ecosystem-Level Reference Points			Short
				Explore best measures of cross-pressure, cumulative impacts in an ecosystem (in conjunction with Section 2.3.)	Short-Mid
				Develop Ecosystem-level reference points and Thresholds	Mid
	5b	Ecosystem considerations for LMRs	Appropriately include ecosystem-factors in crafting advice for managed species	Develop and track fishery stock status indices that denote when ecosystem considerations are used	Mid
		Incorporate Ecosystem Considerations into Appropriate LMR Assessments, Control Rules, and Management Decisions			
	5c	Integrated Advice for other Management Considerations	Systematically evaluate advice provided	Explore protocols for considering ecosystem-level information in EFH reviews, identifying ecosystem-level habitat areas of particular concern, and setting habitat conservation objectives and/or indicators	Short
		Provide Systematic Advice for other Management Considerations, particularly Applied Across Multiple Species within an Ecosystem		Finalize National Bycatch Reduction Strategy	Short
				Evaluate the ecosystem effects of offshore aquaculture	Long
				Review long-term protected species recovery and rebuilding plans to ensure they account for the potential effects of near-term and long-term climate change, particularly relating to alterations to food web structure	Long

[5]In conjunction with NGSA & SAIP update, NCSS, and HAIP

[6] http://www.st.nmfs.noaa.gov/stock-assessment/stock-assessment-prioritization

2.6 Maintain resilient ecosystems— Guiding Principle 6

NOAA Fisheries recognizes that its mandates are intended to sustain resilient and productive LMR populations and habitats, maintain overall ecosystem structure and function, and support the contributions that fisheries make to the socio-economic resiliency of coastal communities. Implementation of EBFM will require NOAA Fisheries to develop operating protocols that maintain resilient ecosystems. Actions in support of these mandates include:

- Evaluate ecosystem-level measures of resilience to maintain core ecosystem structure, biodiversity, production, energy flow, and functioning
- Evaluate coastal fishing community well-being

2.6.1 Evaluate ecosystem-level measures of resilience (Guiding Principle 6a)

Ultimately, humans are part of marine ecosystems and human communities need the ecosystem goods and services provided by the nation's managed species and functioning marine ecosystem. Maintaining and monitoring the status of marine ecosystems, as well as supporting the coastal communities that rely on them, are critical for evaluating the success of EBFM. To this end, NOAA Fisheries will track those ecosystem-level reference points that can be used as measures of ecosystem-level resilience.

2.6.2 Evaluate community well-being (Guiding Principle 6b)

NOAA Fisheries is required, consistent with the conservation requirements of the MSA, to take into account the importance of fishery resources to fishing communities by using the best available social and economic data, in order to provide for the sustained participation of such communities and, to the extent practicable, mitigate adverse economic impacts on such communities (16 U.S.C. §1851(a)(8)). NOAA Fisheries will also track those ecosystem-level reference points that can be used as measures of community well-being.

Recommended Actions

EBFM Policy Statement Guiding Principles	#	EBFM Road Map Core Components	Overarching Goal	Action Items	Timing
Maintain Resilient Ecosystems					
	6a	Evaluate Resilience	Develop and achieve ecosystem performance measures	Track Ecosystem-level reference point to assess changes in ecosystem-level resilience	Ongoing
		Evaluate Ecosystem-Level Measures of Resilience		Track and conduct valuation of Ecosystem Goods and Services relative to benchmarks	Long
	6b	Community Well-being	Maintain well-being of coastal communities	Track community health socio-economic metrics	Medium-Ongoing
		Evaluate Community Well-being		Establish National EBFM Coordinator	Immediate

3.0 Execution of the EBFM Road Map and Effective Dates

The elements of the EBFM Policy and EBFM Road Map afford the opportunity to improve how we manage our nation's living marine resources. Actions noted herein have longer-term timelines built into them that can help track progress toward EBFM implementation. NOAA Fisheries will review and amend this guidance on a five-year basis. Road Map implementation will start one month after the final clearance date of the Road Map. This Road Map will provide the metrics by which Agency progress is evaluated.

This Road Map includes recommended actions to guide NOAA Fisheries as it implements EBFM. These require active management. Some of the recommended actions are on-going and will continue. Some of the recommended actions constitute new activities, where existing or new resources would have to be allocated to accomplish the actions. Close cooperation among the FSC, RO, FMCs, Tribes and States will be required to complete the trade-off analyses needed to inform NOAA Fisheries decision makers. This Road Map will help direct the activities of NOAA Fisheries staff at a large number of offices and laboratories. For successful implementation, the connection between the actions recommended herein and the many laboratories, divisions, and branches of NOAA Fisheries is critical, as well as connections among NOAA Fisheries and key stakeholders

Within each Financial Management Center within NOAA Fisheries over the next one to two years, NOAA Fisheries Leadership will begin to develop a specific set of milestones to address EBFM elements in this Road Map. As part of regular strategic planning and annual planning processes, these milestones will be prioritized. Implementation of EBFM activities will therefore be an integral part of the annual allocation of appropriated funding for each region. Within fifteen months of the release of this Road Map, each NOAA Fisheries region, using the development of their regional engagement strategies (section 2.1) as an organizing theme, will combine ongoing facets of NCSS Regional Action Plans, NGSA Stock Assessment Priorities, HAIP Habitat Prioritization, and specific systematic EBFM elements noted herein, into a regional EBFM implementation plan with specific milestones.

As noted earlier, NOAA Fisheries will convene a biennial meeting regarding EBFM. Participants will include staff representing the NOAA Fisheries science and regulatory enterprises. The primary focus of this meeting will be to review progress in implementing EBFM in NOAA Fisheries and exchange best practices for doing so. The metrics identified in this Road Map will form the basis for this evaluation.

Once the Road Map is finalized, a protocol for providing national oversight among the FSCs, ROs, and Headquarters will be developed and implemented. Oversight for EBFM implementation will be based on best practices developed nationally and the principles codified in this document. Annual updates will provide an evaluation of EBFM progress. This coordination of efforts to implement EBFM will provide an agency-level

understanding of progress toward these goals; to facilitate this, a national EBFM coordinator will be established, along with POCs in each FSC, RO, and HQ office. The application of best practices, identified during the annual updates and the biennial meetings, should provide for an efficient and effective way for NOAA Fisheries to improve on its stewardship responsibility for its trust resources. This will be an evolutionary process, where progress will be based on previous accomplishments. EBFM is only achievable with broad support, yet NOAA Fisheries and its many partners will benefit from implementing EBFM as described in this Road Map.

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Figure 1. The location of Regional Offices (RO), Fishery Science Centers (FSC), Fishery Management Councils (FMCs; Northeast, Mid Atlantic, South Atlantic, Caribbean, Gulf of Mexico, Pacific, North Pacific, West Pacific), Interstate Fishery Commissions (SFCs; Atlantic, Pacific, Gulf; Great Lakes not noted), Large Marine Ecosystems (LMEs; Beaufort, Chukchi, Eastern Bering Sea, Aleutian Archipelago, Gulf of Alaska, California Current, Insular Pacific/Hawaiian, Gulf of Mexico, SEUS, NEUS, Caribbean, Antarctic – not shown), and the US Economic Exclusive Zone (EEZ) for which NOAA Fisheries and its partners have jurisdiction and are mandated to manage LMRs and marine ecosystems. The Antarctic (CCAMLR), Arctic, and regional fishery management organizations (RFMOs; i.e. CCAS, IPHC, IWC, ICCAT, NASCO, NAFO, WECAFC, ITTAC, PSC, NPAFC, WCPFC, AIDCP, IOTC, IOSEA, IAC, ACAP, CBD, CITES, UNFSA, COFI), often associated with the high seas, are not denoted. Nor are the Science Review Groups (SRGs) for marine mammals (Pacific, Atlantic, Gulf).

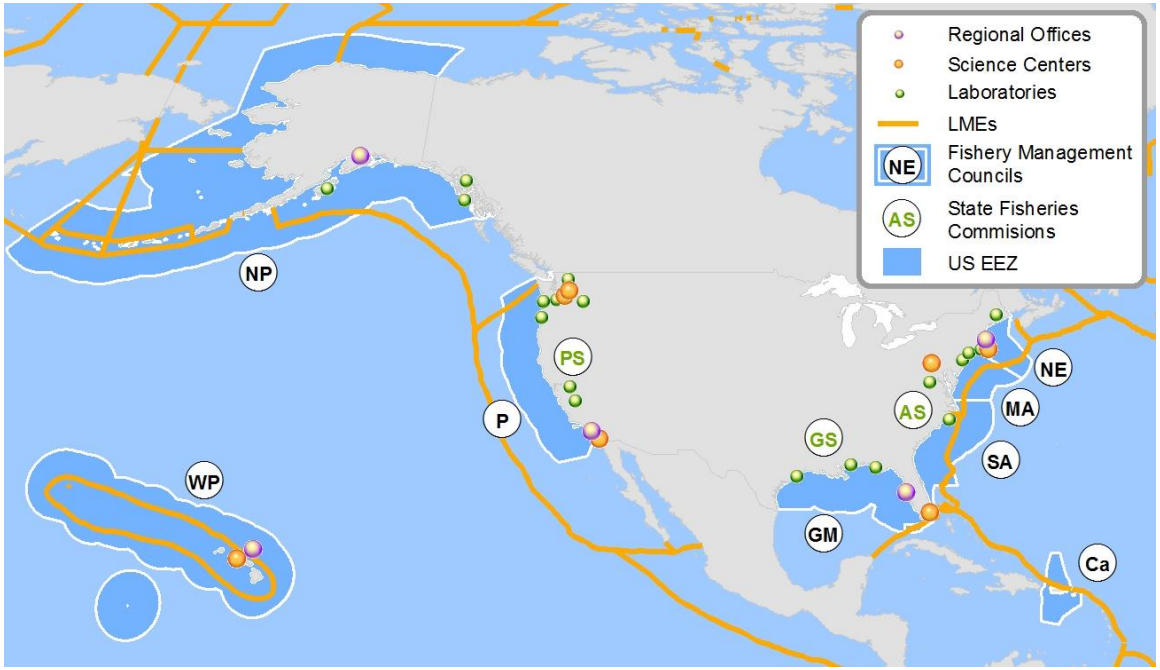
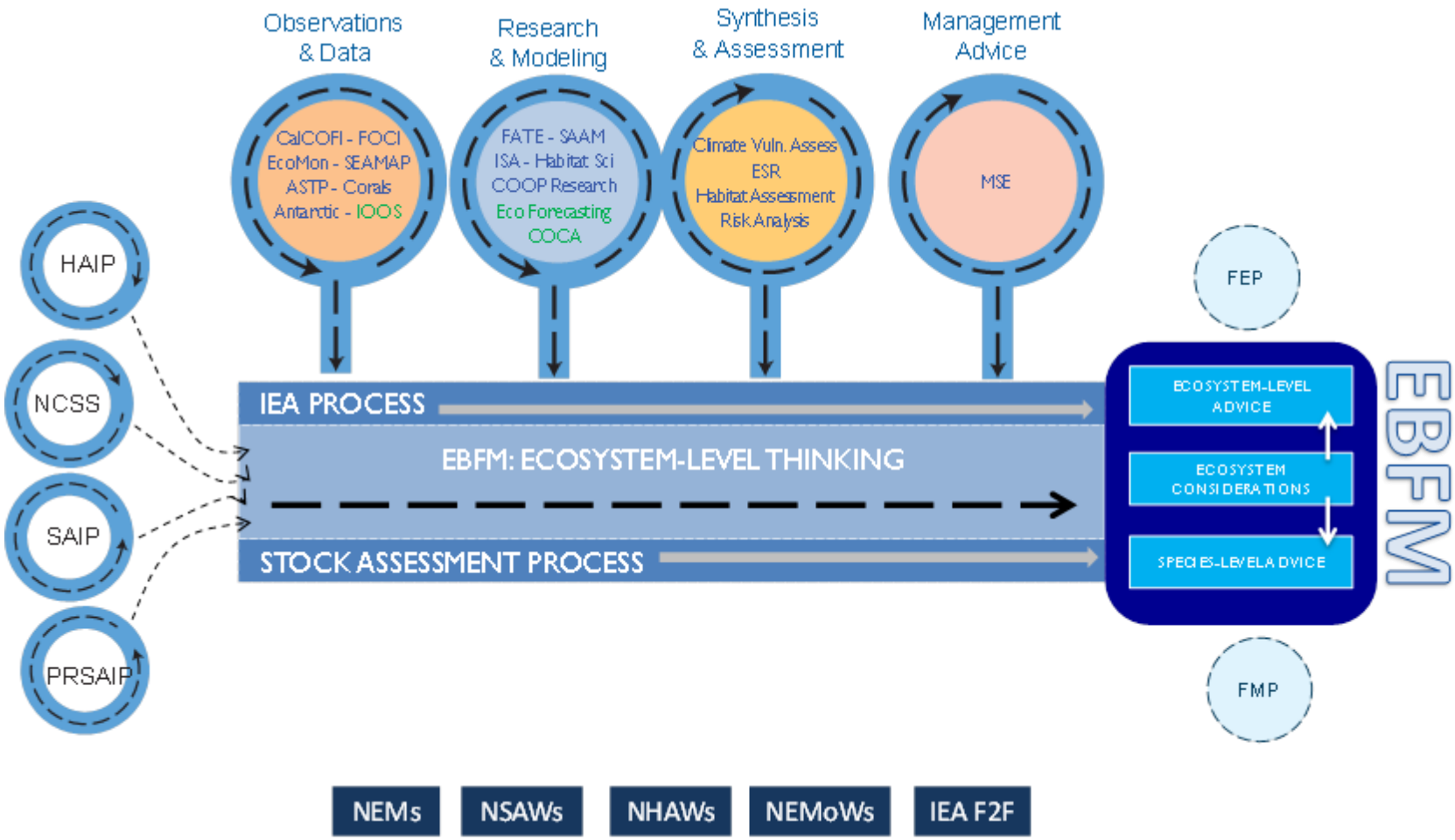
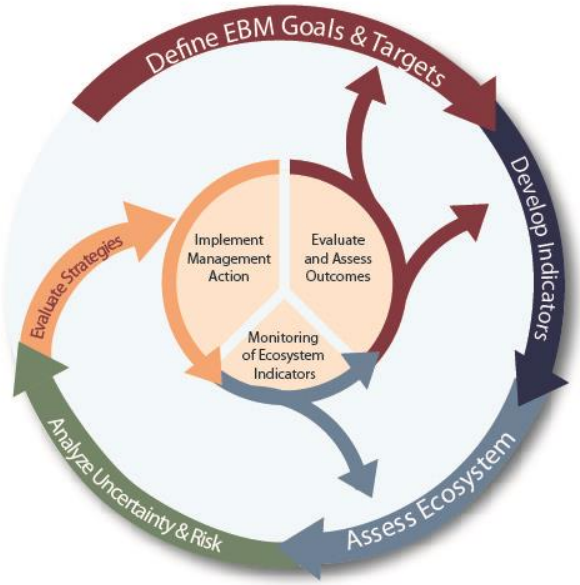
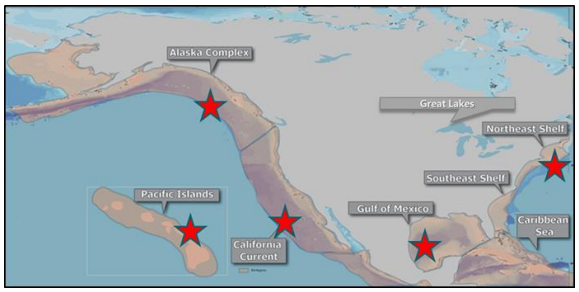


Figure 2. Inter-relationships among NOAA Fisheries programs and plans that support EBFM. See list of acronyms in the back for definitions.



Box 1. NOAA's Integrated Ecosystem Assessment (IEA) Program: An analytical framework to deliver management advice in an ecosystem context





NOAA's Integrated Ecosystem Assessment (IEA) program is an end-to-end framework that enables the implementation of EBM, including EBFM, to provide resource managers with ecosystem-specific information to make more informed and effective management decisions. While IEAs are designed to enable full multisector EBM, they support needs along the ecosystem management continuum by providing an ecosystem context to traditional single-sector decisions, such as fisheries management.

NOAA's IEA is a science-based stepwise process implemented with stakeholders and managers to identify priority issues and provide robust decision-support information in an ecosystem context. The approach identifies socio-economic and biophysical attributes that maintain ecosystem structure and function, assesses human activities and their interdependence with the natural ecosystem, and evaluates trade-offs of management alternatives to sustain human well-being in the coupled social-ecological system.

Though IEAs share a common national framework, the implementation varies regionally based on the ecosystem of interest and the management drivers. The overarching goal is to inform decisions that will promote ecosystems that are both sustainable and capable of providing the diverse ecosystem services upon which our society depends.

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Box 2—Levels of EBM

"Ecosystem management" can be adopted at multiple levels. Some levels of application are focused solely on fish stocks, some focus on fish stocks but with ecosystem considerations incorporated (ecosystem approach to fisheries management, EAFM), some focus solely on the fisheries sector but for the full system of fisheries and stocks (EBFM), and others focus on the full set of ocean-use sectors impacted by and impacting the fisheries sector (EBM). For example, consider forage stocks such as small pelagic fish. For an EAFM, one would need to consider the effects of environmental factors (e.g., temperature changes or North Atlantic Oscillation events) and ecological factors (e.g., predator removals or models of multispecies interactions) in addition to targeted fisheries removals to truly grasp what is driving the population dynamics of such stocks. Using the same type of focal species as an example, for EBFM that takes a system focus in the fisheries sector, one would have to consider not only the impacts of other factors on these forage stocks, but also the dynamics of these forage stocks on other parts of the ecosystem. For instance, some seabirds and marine mammals have some form of protected or conservation status and are highly dependent on small pelagic forage fish. Some commercially targeted groundfish are also major predators of these small pelagic forage fish. In addition, multiple fisheries operate on both the groundfish and the small pelagic species. In such a case, clearly a more integrated, "bigger picture" evaluation of the whole system and how it fits together is needed to address the potential trade-offs among the different uses of and impacts to these forage stocks. Further, if these forage stocks represent a key pathway of energy from lower trophic levels to upper trophic levels (which they typically do), then the resilience, structure, and functioning of the system would need to be evaluated. For an EBM that covers all ocean-use sectors, consideration of these small pelagics and their role in the ecosystem is warranted in a broader context for anthropogenic drivers such as power plant discharges (thermal impacts), eutrophication, toxin deposition, hydroelectric energy generation, dredging for navigation safety, and similar uses that might impact the habitats of these species.

Certainly the lines among the different levels are somewhat blurry, but defining the level of analysis and management being done helps to dispel concerns associated with linguistic uncertainty for such a comprehensive topic.

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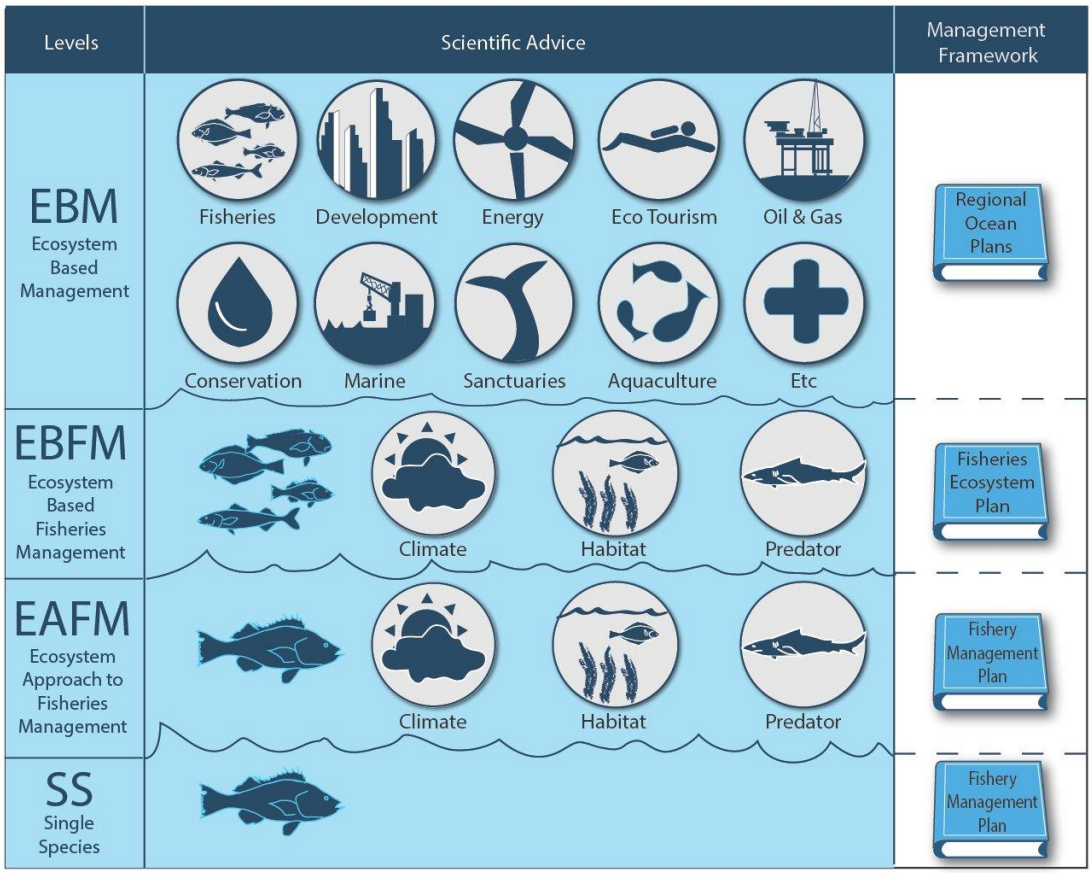
Box 2—Levels of EBM



Box 3. Conceptual models guide science and provide for stakeholder engagement in support of EBFM in the California Current

NOAA's Integrated Ecosystem Assessment (IEA) program is developing *conceptual models* that distill marine ecosystems down to their essential elements. Conceptual models convey the intricacy of an ecosystem's structure and function in a way that facilitates further discussion of priorities, objectives, and trade-offs without miring viewers in excessive detail. These models are developed in conjunction with NOAA Fisheries partners and stakeholders to assist in identifying the most pressing issues in any given region.

The California Current IEA team has developed a series of conceptual models to illustrate the key relationships between focal species groups and physical drivers, habitats, other species, human activities, and human well-being. These elegant models were derived through extensive, consensus-based discussions with a range of stakeholders, and are readily adaptable as new information becomes available. Models exist for target species (coastal pelagic species, salmon, and groundfish) and protected species (seabirds and marine mammals); new models are being developed for major habitat types, and for the diverse human-natural interactions that characterize the socio-ecological nature of the California Current.

These conceptual models have already proven their value as communication tools. The California Current IEA team uses them in discussions with the Pacific Fishery Management Council and other groups. Each symbol and line represents indicators that the IEA team is analyzing to track ecosystem status and management effectiveness. These models thus set the stage for more detailed discussions, and IEA scientists are using mathematical approaches to convert them from simple illustrations into dynamic simulation models.

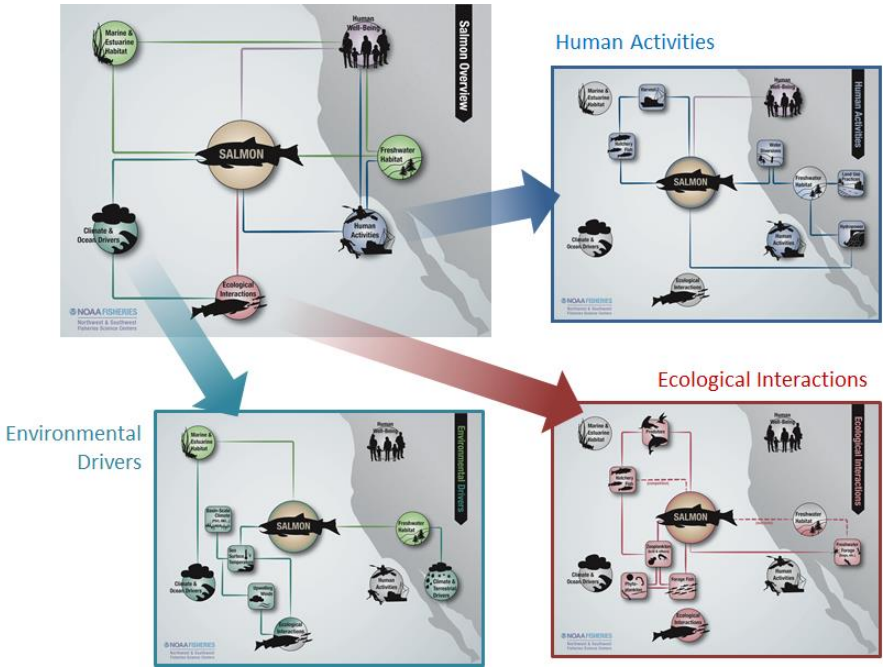


Figure. Conceptual model of the roles of Pacific salmon in the California Current Ecosystem. The general summary model (upper left) expands to detailed submodels of interactions between the focal species and environmental, ecological, and human components. (Illustrations: Su Kim, NOAA)

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Box 4. Description of FEPs and general use

Ten Fishery Ecosystem Plans (FEPs) are currently being used by four Fishery Management Councils (North Pacific, Pacific, Western Pacific, and South Atlantic). Each FEP covers similar ideas and principles, and varies depending on the needs of a specific Council and the fisheries and ecosystems under their jurisdiction. For example, the Pacific Council has set up their FEP to create a framework for setting policies and priorities to be implemented through Fishery Management Plan (FMP) amendments and for tracking progress through a set of indicators. In some cases, the FEPs are compilations of ecosystem information with a strong focus on habitat that support implementation of MSA essential fish habitat. Others, such as the Aleutian Islands FEP, are primarily reference documents of ecosystem information to facilitate efficient implementation through FMPs. The Western Pacific Council FEPs contain conservation and management measures and meet the requirements of FMPs, but reflect groupings of managed stocks around geographically defined island/archipelago areas and are called FEPs. Most of the Councils also supplement their FEPs with additional documents such as ecosystem chapters of Stock Assessment and Fishery Evaluation reports, stock assessments, and FMP amendments. Using supplemental documents has made it easier for some of the Councils to update crucial ecosystem-related information without having to update an entire FEP.

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Box 5. Ecosystem Status Reports

Ecosystem Status Reports (ESRs) are a key element of the NOAA Fisheries EBFM Road Map. These regularly updated reports provide a vehicle for disseminating information on the state of regional ecosystems. They describe the dynamic interplay of natural and anthropogenic drivers and resulting changes in different parts of the ecosystem These status reports are intended to concisely convey to stakeholders, managers, and the general public how marine ecosystems are responding to different stressors and to natural environmental change. By monitoring the pulse of ecosystem change, we hope to identify early warning signals of changes within systems. NOAA's IEA Program plays a critical role in synthesising ecosystem information and capturing it in ESRs for each region. The main findings are translated to management partners, including to Regional Fishery Management Councils and Interstate Fishery Commissions throughout the nation to help guide management actions, particularly to consider the system as a whole and not just its parts.

An example is the current Northeast Region ESR, an entirely web-based product that can be viewed on a number of devices (including smartphones and tablets) through its use of Responsive Design technology (c.f. http://www.nefsc.noaa.gov/ecosys/). The New England Fishery Management Council has requested annual spring updates based on a distillation of the ESR in the form of a brief State of the Ecosystem Report to help provide an ecosystem context for its deliberations. Similar applicatiions are now underway in other parts of the country (http://www.noaa.gov/iea/transfer-knowledge/science-supporting-ecosystem-status.html).

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Box 6. Aggregate Risk Assessment

Risk assessment methods are used worldwide to evaluate potential threats to living marine resources, and to prioritize management of these threats. For example, a semi-quantitative risk analysis for aggregate fish communities in the Northeast United States was used to identify priorities for further detailed assessment (Gaichas *et al.*, 2015). A place-based, functional group approach was taken to provide information on threats for comprehensive categories of regional fishery resources, rather than attempting to do so for individual species. In this example, climate-driven risks were the focus of the risk assessment because some of the largest observed rates of sea surface temperature increase within U.S. marine ecosystems are on the northeast U.S. continental shelf. Climate vulnerability across two ecosystems (the Gulf of Maine (GOM) and Mid-Atlantic bight (MAB)) was evaluated for six communities (both commercial and non-commercial demersal fish, pelagic fish, and benthic invertebrates, respectively). First, the probability that anticipated effects of climate change (e.g., warming water, decreased salinity, increased acidity, and altered boundary currents) would occur in these regions was evaluated, and the potential severity of change over the next 10 years was rated. Then, the sensitivity of each biological community in each region was evaluated using 12 attributes (e.g., habitat and prey specificity, temperature and acidity sensitivity, larval dispersal, adult mobility, population productivity, among others). Risks to living marine resources from increased surface water temperature, sea level rise, and earlier spring were rated moderate to high in both regions, with additional moderate to high risks in the GOM from increased bottom temperature, stratification, and river inputs. The figure shows that benthic invertebrates were rated most sensitive, with demersals intermediate and pelagics lowest. Two MAB communities were rated more sensitive than corresponding GOM communities, but greater short-term risks in the GOM indicated increased exposure for GOM communities. Overall, this simple analysis may help prioritize short-term regional climate risk management action for many fished and unfished resources, and show where more specific assessment is warranted.

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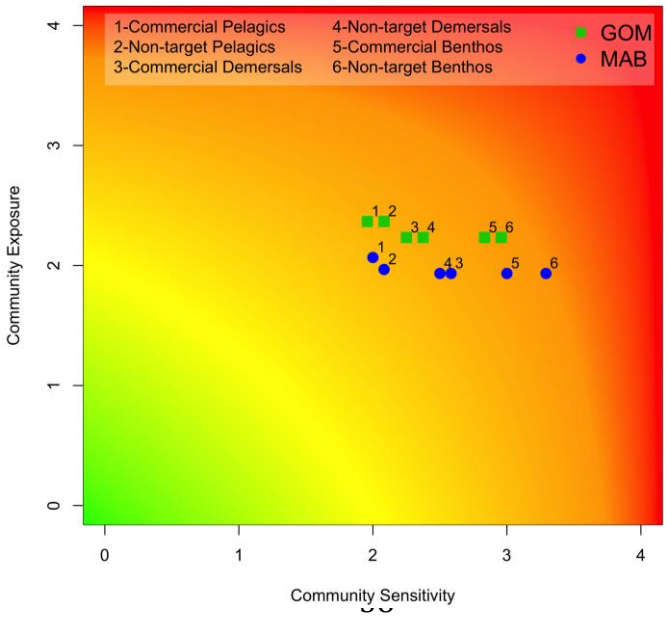
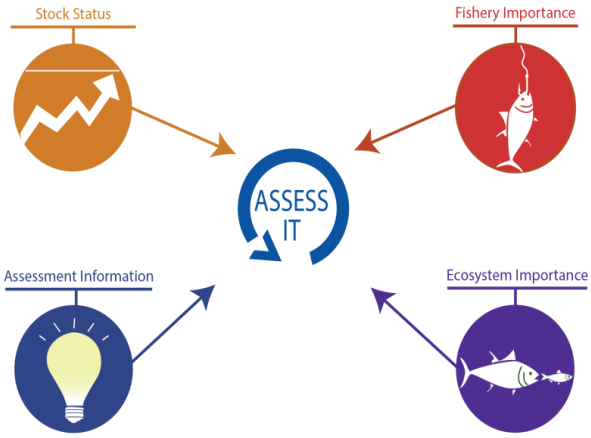


Box 7. Stock assessment prioritization and ecosystem-linkages

NOAA Fisheries conducts stock assessments and provides fishery managers with scientific advice to support the sustainable management of nearly 500 fished stocks. There are limitations on the number of assessments that can be done each year, and on the amount and types of data collected for those assessments. Also, each stock is unique in its biology, its economic importance, and how it responds to fishing; hence, no single stock assessment approach is appropriate for all stocks. Recognizing the need for a process that maximizes stock assessment capacity in support of fisheries management, NOAA Fisheries recently released a national protocol for prioritizing stock assessments.[6] The prioritization process is being implemented at a regional scale, and is intended to identify which stocks in a given region are candidates for stock assessments, the frequency by which assessments should be conducted for each stock, and the level (i.e., ideal data inputs and analytical complexity) at which those assessments should be conducted. This process provides regional planning bodies with an objective approach to determine which, when, and at what frequency stock assessments should be conducted, along with the data requirements associated with those assessments. Ecosystem data—including information on predator-prey dynamics, habitats, and physical and chemical properties of the ocean—are candidate inputs for stock assessments. Thus, through the assessment prioritization process, NOAA Fisheries will evaluate relationships between stocks and their ecosystems to provide guidance on which assessments should incorporate ecosystem factors. In the first phase of implementation, the prioritization process is primarily focused on identifying stocks that are candidates for assessments and on setting target assessment frequencies for those stocks. Additionally, habitat assessment prioritization processes have been completed in three NOAA Fisheries regions to identify species that would most benefit from habitat information included in stock assessments (NMFS 2011).



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[6] http://www.st.nmfs.noaa.gov/stock-assessment/stock-assessment-prioritization

Box 8. Two million metric ton cap for the Bering Sea and Aleutian Islands groundfish fishery

One tool that the North Pacific Fisheries Management Council uses to prevent overfishing in the eastern Bering Sea and Aleutian Islands (BSAI) is the 2 million metric ton (M mt) optimum yield cap for the BSAI groundfish fisheries. The cap is an upper limit on the total amount of groundfish that can be harvested from the BSAI each year. The allowable catch limit (ACL) for the BSAI typically is greater than 2Mmt and in these years, the cap constrains total BSAI catch. The cap was established in 1984. As a result, many stocks, particularly flatfish, have been exploited well below sustainable levels for the individual flatfish species (Witherell 1995).

This cap is a measure of ecosystem productivity and the amount of fish protein that can be removed sustainability. A system cap that constrains individual species caps was chosen because ecological relationships in the BSAI are complex (NPFMC 1995). The cap was derived from the sum of the maximum sustainable yields of the individual species, referenced with the results of an ecosystem model of the Bering Sea, and adjusted downward for incomplete data and uncertainty in stock assessment models (NPFMC 1995).

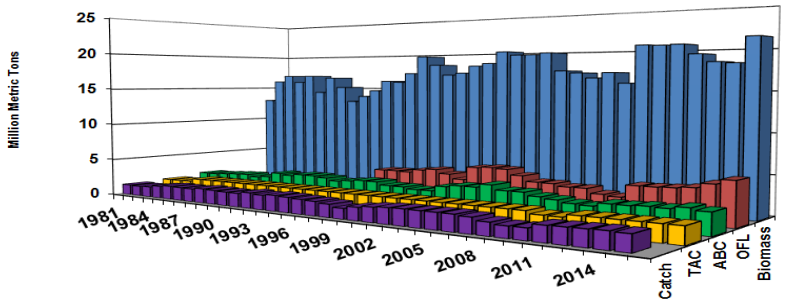

Figure. Catch, total allowable catch (TAC), allowable biological catch (ABC), overfishing limit (OFL), and total biomass of groundfish in the Bering Sea and Aleutian Islands.

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Box 9. Fisheries Stock Assessments with ecosystem information

NOAA Fisheries conducts stock assessments to produce scientific advice for fishery managers. The main objectives of fishery stock assessments are to evaluate stock status relative to defined limits, and to recommend harvest levels that optimize yield, prevent overfishing, and rebuild depleted stocks as necessary. In most cases, assessments are conducted from a single-species perspective, where ecosystem and environmental factors are not explicit drivers of stock dynamics, but are assumed to either be constant or to contribute to unexplained variation in stock abundance or biology. However, for a number of stocks, ecosystem information has been directly incorporated into assessment models, thereby providing fishery managers with stock-specific advice that accounts for changes in the ecosystem. West Coast salmon forecasts are informed by numerous ocean and ecosystem indicators. The North Pacific groundfish stocks, West Coast small pelagics, and the butterfish stock in the northeast Atlantic incorporate water temperature into their assessments, because this variable affects the number of fish encountered by abundance surveys. Finally, for Atlantic herring, northern shrimp, and Gulf of Mexico groupers, the numbers that die due to natural causes (i.e., natural mortality) is modeled using ecosystem indices. With herring, an important prey species in the northeast Atlantic, predator dynamics are incorporated into the stock assessment. For groupers, a red tide index is incorporated in the stock assessments, as fishermen and scientists have observed mass mortality events when there are substantial red tides (i.e., harmful algal blooms).

The number of assessments that incorporate ecosystem data has continued to increase over time. In 2005, 4% of the stock assessments conducted by NOAA Fisheries in that year included ecosystem factors, and by 2015 that number increased to 8%. As research and monitoring of stock and ecosystem dynamics continues to expand, the number of stock assessments and management measures that consider ecosystem variability and change will continue to increase.

Box 9 cont.

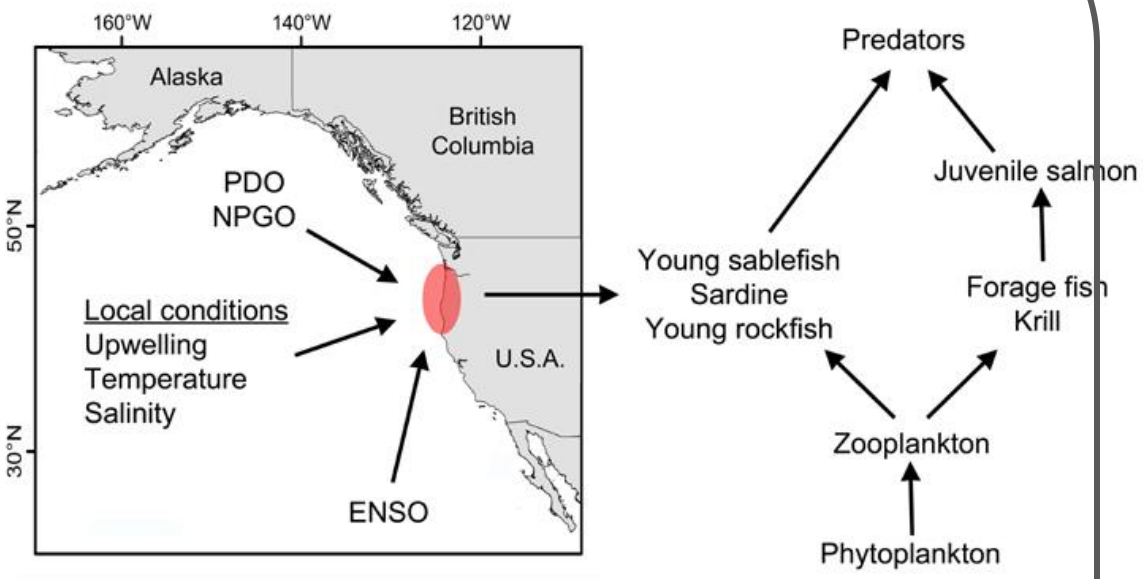

Figure. Illustration of how basin-scale and local-scale physical forces influence the northern California Current and resultant food web structure. PDO = Pacific Decadal Oscillation. NPGO = North Pacific Gyre Oscillation. ENSO = El Niño–Southern Oscillation. Figure from Peterson et al. 2014 Oceanography 27(4):80-89.

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Box 10. Interdisciplinary approach to estimate Multi-Species harvest control rules and reference points

Through a partnership between NOAA Fisheries, the North Pacific Research Board, and the National Science Foundation, (the Bering Sea Project, http://www.afsc.noaa.gov/HEPR/bseirp.htm) scientists have advanced the mechanistic understanding of Bering Sea processes governing fish responses to climate variability, which resulted in a modeling framework to explore trophic interactions and climate change impacts on key species within the eastern Bering Sea. Analysts extended the data-rich single species stock assessment model for walleye pollock in the eastern Bering Sea (Ianelli 2005) and a simulation model of the Bering Sea foodweb, Ecosim (Aydin and Mueter 2007) to explore alternative harvest strategies under changing climate conditions. These enhancements utilized diet data derived from Alaska Fisheries Science Centers's food-habits data collections (http://access.afsc.noaa.gov/REEM/WebDietData/DietTableIntro.php). A climateenhanced multispecies stock assessment was developed to incorporate species interactions between pollock and two of the main Bering Sea piscivorous groundfish (Pacific cod and arrowtooth flounder) (Holsman et al. In Press). The application of traditional harvest control rules within a multi-species model yielded regions of sustainable harvest levels rather than a single solution. Scientists utilized the Ecosim model to define this surface for Pacific cod and walleye pollock (Figure) (Moffitt et al. In Press) and they explored the effect of changing temperature on predator and prey interactions and subsequent climate-specific multispecies biological reference points (via CEATTLE; Holsman et al. In Press). Though there are many other multi-species interactions (e.g., Steller sea lions, arrowtooth flounder) and climate features to consider, these projections will help the North Pacific Fishery Management Council and its scientific review teams to develop strategies for managing fisheries under non-stationary population processes (Szuwalski and Hollowed 2016, http://www.afsc.noaa.gov/News/BS_climate-change-study.htm).

Box 10 cont.

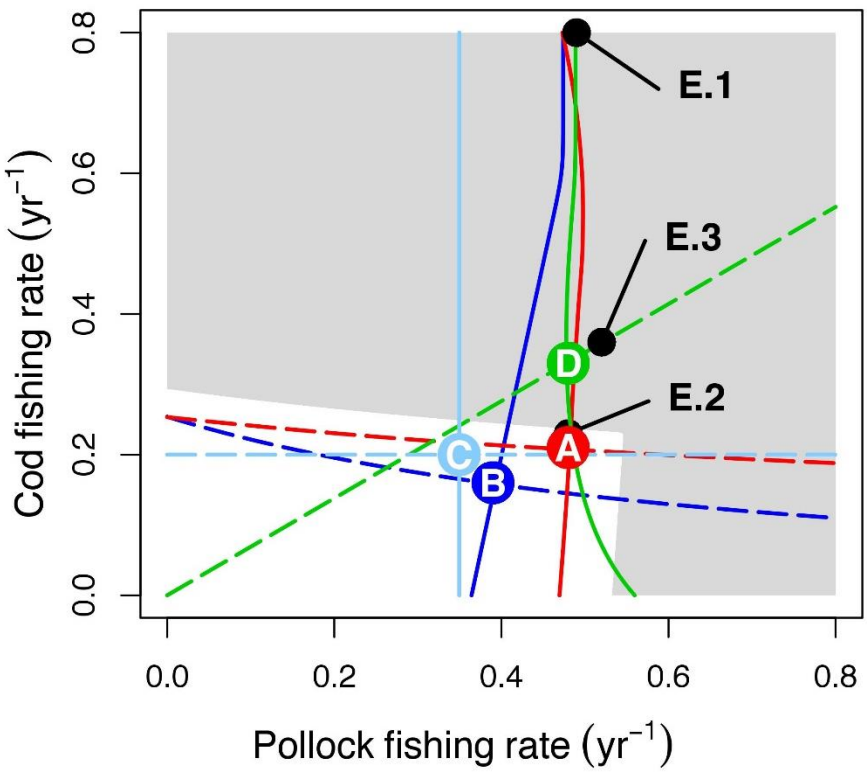

Figure. Candidate multi-species biological reference points modeled as a function of pollock and cod fishing mortality rates (Moffitt et al. In Press). Letters refer to different candidate multispecies biological reference points (A: solve for $F_{x\%}$ by species when fishing mortality for all other species is set to current average values; B: solve for $F_{x\%}$ by species when fishing mortality for all other species is set to zero; C: calculate $F_{x\%}$ when M-at-age for each species is set to the values at B_0; D: $x*B_0$ would apply over all species combined, F_{MSY} for each species would be a scalar multiplied by M; E1: unconstrained optimization; E2 constrained so no stock falls below $y*B_0$; and E3: unconstrained with relative fishing mortality pre-specified. The gray area represents the "single-species" overfishing limit (fishing rate $>F_{35\%}$ when in Option A).

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List of Acronyms

ABC - Allowable Biological Catch
ACAP - Agreement on the Conservation of Albatrosses and Petrels
ACL - Annual Catch Limit
AIDCP - Agreement on the International Dolphin Conservation Program
CBD - Convention on Biological Diversity
CCAMLR - Conservation of Antarctic Marine Living Resources
CCAS - Convention for the Conservation of Antarctic Seals
CITES - Convention on International Trade in Endangered Species
COFI - Committee on Fisheries
E2E - End to End models
EBM - Ecosystem-Based Management
EBFM - Ecosystem-Based Fisheries Management
EFH - Essential Fish Habitat
ELRP - Ecosystem-Level Reference Point
EPAP - Ecosystem Principles Advisory Panel
ESA - Endangered Species Act
ESR - Ecosystem Status Report
FATE - Fisheries and the Environment
FEP - Fishery Ecosystem Plans
FMC - Fishery Management Council
FMP - Fishery Management Plan
FSC - Fisheries Science Center
FTE—Full Time Equivalent
FY - Fiscal Year
HAIP—Habitat Assessment Improvement Plan
HAPWG - Habitat Assessment Prioritization Working Group
HAPC - Habitat Area of Particular Concern
HCR - Harvest Control Rule
IAC - Inter-American Convention
ICCAT - International Commission for the Conservation of Atlantic Tunas
ICES - International Council for the Exploration of the Sea
IEA - Integrated Ecosystem Assessment
IGO - Inter-Governmental Organization
IOSEA - The Indian Ocean - South-East Asian
IOTC - Indian Ocean Tuna Commission
IPHC - International Pacific Halibut Commission
ITTAC - International Commission for the Conservation of Atlantic Tunas
IWC - International Whaling Commission
LME - Large Marine Ecosystem
LMR - Living Marine Resource
MSE - Management Strategy Evaluation
MMPA - Marine Mammal Protection Act
MSA—Magnuson-Stevens Act
MSY - Maximum Sustainable Yield
NAFO - Northwest Atlantic Fisheries Organization
NAO - North Atlantic Oscillation
NASCO - North Atlantic Salmon Conservation Organization
NCSS - National Climate Science Strategy
NEMoW - National Ecosystem Modeling Workshop
NEPA - National Environmental Protection Act
NGO - Non-governmental Organization
NGSA - Next Generation Stock Assessment
NHAW - National Habitat Assessment Workshop
NPAFC - North Pacific Anadromous Fish Commission
NSAW - National Stock Assessment Workshop
NRC - National Research Council
NSF - National Science Foundation
OFL - Overfishing Limit
OSP - Optimum Sustainable Population
OY - Optimum Yield
PBR - Potential Biological Removal
PR-SAIP - Protected Species Stock Assessment Improvement Plan
PSA - Productivity and Susceptibility Analysis
PSC - Prohibited Species Catch
RO - Regional Office
SA - Stock Assessment
SAIP - Stock Assessment Improvement Plan
SSC - Scientific and Statistical Committee
TAC - Total Allowable Catch
TOR-- Terms of Reference
UNFSA - United Nations Fish Stocks Agreement
VES-V - Virtual Ecosystem Scenario Viewer
WCPFC - Western & Central Pacific Fisheries Commission
WECAFC - Western Central Atlantic Fishery Commission